Flavonoid (Myricetin, Quercetin, Kaempferol, Luteolin, and Apigenin) Content of Edible Tropical Plants

Koo Hui Miean and Suhaila Mohamed*

Faculty of Food Science and Biotechnology, University Putra Malaysia, 43400 Serdang Selangor, Malaysia

Studies were conducted on the flavonoids (myricetin, quercetin, kaempferol, luteolin, and apigenin) contents of 62 edible tropical plants. The highest total flavonoids content was in onion leaves (1497.5 mg/kg quercetin, 391.0 mg/kg luteolin, and 832.0 mg/kg kaempferol), followed by Semambu leaves (2041.0 mg/kg), bird chili (1663.0 mg/kg), black tea (1491.0 mg/kg), papaya shoots (1264.0 mg/kg), and guava (1128.5 mg/kg). The major flavonoid in these plant extracts is quercetin, followed by myricetin and kaempferol. Luteolin could be detected only in broccoli (74.5 mg/kg dry weight), green chili (33.0 mg/kg), bird chili (1035.0 mg/kg), onion leaves (391.0 mg/kg), belimbi fruit (202.0 mg/kg), belimbi leaves (464.5 mg/kg), French bean (11.0 mg/kg), carrot (37.5 mg/kg), white radish (9.0 mg/kg), local celery (80.5 mg/kg), limau purut leaves (30.5 mg/kg), and dried asam gelugur (107.5 mg/kg). Apigenin was found only in Chinese cabbage (187.0 mg/kg), bell pepper (272.0 mg/kg), garlic (217.0 mg/kg), belimbi fruit (458.0 mg/kg), French peas (176.0 mg/kg), snake gourd (42.4 mg/kg), guava (579.0 mg/kg), wolfberry leaves (547.0 mg/kg), local celery (338.5 mg/kg), daun turi (39.5 mg/kg), and kadok (34.5 mg/kg). In vegetables, quercetin glycosides predominate, but glycosides of kaempferol, luteolin, and apigenin are also present. Fruits contain almost exclusively quercetin glycosides, whereas kaempferol and myricetin glycosides are found only in trace quantities.

Keywords: *Flavonoids; edible tropical plants; myricetin; quercetin; kaempferol; luteolin; apigenin*

INTRODUCTION

Flavonoids demonstrate a wide range of biochemical and pharmacological effects including anti-oxidation, anti-inflammation, anti-platelet, anti-thrombotic action, and anti-allergic effects (*1*−*4*). They can inhibit enzymes such as prostaglandin synthase, lypoxygenase, and cyclooxygenase, closely related to tumorigenesis (*5*, *6*), and induce detoxifying enzyme systems such as glutathione S-transferase (*7*). Quercetin inhibited oxidation and cytotoxicity of low-density lipoprotein in vitro (*8*), and can reduce risk for coronary heart disease or cancer (*9*). An in vitro oxidation model showed quercetin, myricetin, and rutin being more powerful antioxidants than the traditional vitamins (*10*). Flavonols and flavones possess antioxidant and free radical scavenging activity in foods (*11*), and have significant vitamin C sparing activity (*3*), with myricetin being one of the most active (*12*). In vegetables, quercetin glycosides predominate, but glycosides of kaempferol, luteolin, and apigenin are also present. Fruits almost exclusively contain quercetin glycosides, whereas kaempferol and myricetin glycosides are found only in trace quantities (*13*).

Flavonoids are polyphenols with diphenylpropanes ($C_6C_3C_6$) skeletons. The four major classes are the 4-oxoflavonoids (flavones, flavonols, etc.), anthocyanins, isoflavones, and the flavan-3-ol derivatives (catechin and tannins) (*14*). Flavonoids are a large family of over 4000 secondary plant metabolites, many being present as sugar conjugates. Epidemiological studies have indicated a relationship between a diet rich in flavonols and a reduced incidence of heart disease (*15*).

* To whom correspondence should be addressed. Tel: 6-03-9486101. Fax: 6-03-9423552.

The objective of this study was to determine three major flavonols (kaempferol, quercetin, and myricetin) and two major flavones (luteolin and apigenin) in 62 types of edible tropical plants.

MATERIALS AND METHODS

Materials. Raw materials used in this study were belimbi fruits (*Averrhoa belimbi*), belimbi leaves (*Averrhoa belimbi*), guava (*Psidium guajava*), Chinese cabbage (*Brassica oleracea*), cabbage (*Brassica oleracea*), broccoli (*Brassica oleracea*), cauliflower (*Brassica oleracea*), kai lan (*Brassica alboglabra*), winged bean (*Psophocarpus tetragonolobus*), French beans (*Phaseolus vulgaris*), French peas (*Pisum sativum*), lady fingers (*Hibiscus esculentus*), string beans (*Vigna sinensis*), bell pepper (*Capsicum annum*), bird chili (*Capsicum frutescens*), green chili (C*apsicum annum*), red chili (*Capsicum annum*), carrot (*Daucus carota*), white radish (*Raphanus sativus*), garlic (*Allium sativum*), lemongrass (*Cymbopogon citratus*), pandan leaves (*Pandanus odorus*), semambu leaves (*Calamus sciponum*), betel leaves (*Piper betle*), kesom leaves (*Polygonum minus*), Chinese chives leaves (*Allium odorum*), onion leaves (*Allium fistulosum*), drumstick leaves (*Moringa oleifera*), wolfberry leaves (*Lycium chinense*), limau purut leaves (*Citrus hystrix*), red spinach (*Amaranthus gangeticus*), bayam duri (*Amaranthus spinosus*), kangkung (*Ipomoea aquatica*), sweet potato shoot (*Ipomoea batatas*), tapioca shoots (*Manihot utilissima*), cashew shoots (*Anacardium occidentale*), fern shoots (*Diplazium esculentum*), papaya shoots (*Carica papaya*), yam stalks (*Colocasia esculentum*), cekur manis (*Sauropus androgynus*), daun turi (*Sesbania grandifolia*), kadok (*Piper sarmentosum*), local celery (*Apium graveolens*), maman (*Gynandropsis gynandra*), pegaga (*Hydrocotyle asiatica*), selom (*Oenanthe javanica*), brinjal (*Solanum melongena*), angular loofah (*Luffa acutangula*), pumpkin (C*ucurbita maxima*), sengkuang (*Pachyrrhizus erosus*), snake gourd (*Trichosanthes anguina*), mung bean sprouts (*Phaseolus aureus*), soy bean sprouts (*Glycine max*), mint (*Mentha arvensis*), oyster mush-

10.1021/jf000892m CCC: $20.00
Published on Web 05/10/2001

rooms (*Pleurotus sajor-caju*), peria (*Momordica charantia*), petai (*Parkia speciosa*), asam gelugur (*Garcinia atroviridis*), fermented black tea (*Camellia chinensis*), turmeric (*Curcuma longa*), plaintain flower (*Musa sapientum*), and bunga kantan (*Phaeomeria speciosa*). All these materials were obtained from the wet market near the University, or directly from the plants on three occasions, and combined to composites prior to analysis. All the samples were analyzed within three months after acquisition.

The following chemicals were used for determination of flavonoids: methanol HPLC grade and analar grade (BDH Chemical, Poole, England); hydrochloric acid analar grade (BDH Chemical, Poole, England); trifluoroacetic acid (Fluka Chemica). Myricetin, quercetin, kaempferol, luteolin, and apigenin standards were purchased from Sigma Chemicals (St. Louis, MO).

Plant Extraction and Hydrolysis. Five major food flavonoids, viz quercetin, kaempferol, myricetin, apigenin, and luteolin, were determined in dried plant samples after extraction and hydrolysis of the flavonoid glycosides. The plants were cleaned, oven-dried at 40 °C, and ground, and 62.5% aqueous methanol containing 2 g/L TBHQ was added. To every 20 mL of aqueous methanol used was added 5 mL of 6M HCl. Extraction solution thus obtained consisted of 1.2M HCl in 50% aqueous methanol, v/v. These were carefully mixed and refluxed at 90 °C for 2 h. The extract was cooled, filtered using a Büchner filter, made to 50 mL with methanol, and filtered again with 0.45 μm Whatman membrane filter before injection into the HPLC. The extracts were kept in airtight amber bottles and stored in the freezer until analyzed (*16*).

Analysis of Crude Extract. The resultant flavonoid aglycons were quantified by using reversed-phase HPLC on a Nova-Pak C18 (Waters Associates, Milford, MA) column (3.9 $\times$ 150 mm, 4 μm) using methanol/water (50:50 v/v, pH 2.5 with trifluoroacetic acid) as mobile phase and UV detection (365 nm) at the flowrate of 1 mL/min. Chromatograms were compared with the chromatograms of standards to get the results. All the determinations were carried out in duplicate.

Experimental data were analyzed by the analysis of variance (ANOVA) and the significant differences among means were determined by Duncan's multiple range test (DMRT) using the Statistical Analysis System (SAS, 1987) computing program (SAS, Cary, NC).

RESULTS AND DISCUSSION

Screening of Flavonoid Content. The contents of five types of flavonoids, namely myricetin, quercetin, luteolin, kaempferol, and apigenin, in methanol extracts of 62 Malaysian edible plants are shown in Table 1. Among the 62 plant extracts tested, all the species showed significant amounts of flavonoids except sweet potato shoots, winged bean, string bean, petai, peria, bayam duri, betel leaves, plaintain flower, and oyster mushroom. The results clearly indicated that some of the tested plants were rich in these natural antioxidant flavonoids, and the qualities and quantities of the flavonoids in these plants seemed to be very different among the kinds of samples used.

The flavonoid contents of most of the plant extracts tested in this research have not been reported in previous literature. Hertog et al. (*17*) studied the flavonoid content of methanol extracts of 28 vegetables and 9 fruits, and they reported that the quercetin levels in the edible parts of most vegetables were generally below 10 mg/kg except for onion (486 mg/kg), kale (110 mg/kg), broccoli (30 mg/kg), French bean (32−45 mg/kg) and slicing bean (28−30 mg/kg) (Table 2). The contents of myricetin, luteolin, and apigenin were below the limit of detection (<1 mg/kg) except for fresh broad beans (25 mg myricetin/kg) and red bell pepper (13−31 mg luteolin/kg) (Table 2).

The major flavonoid that was found in these plant extracts is the flavonol quercetin, followed by myricetin and kaempferol. Luteolin could be detected only in broccoli (74.5 mg/kg dry weight), green chili (33.0 mg/kg), bird chili (1035.0 mg/kg), onion leaves (391.0 mg/kg), belimbi fruit (202.0 mg/kg), belimbi leaves (464.5 mg/kg), French bean (11.0 mg/kg), carrot (37.5 mg/kg), white radish (9.0 mg/kg), local celery (80.5 mg/kg), limau purut leaves (30.5 mg/kg), and dried asam gelugur (107.5 mg/kg). Apigenin was found only in Chinese cabbage (187.0 mg/kg), bell pepper (272.0 mg/kg), garlic (217.0 mg/kg), belimbi fruit (458.0 mg/kg), French peas (176.0 mg/kg), snake gourd (42.4 mg/kg), guava (579.0 mg/kg), wolfberry leaves (547.0 mg/kg), local celery (338.5 mg/kg), daun turi (39.5 mg/kg), and kadok (34.5 mg/kg).

Hertog et al. (*17*) reported that none of the 28 vegetables and 9 fruits previously tested contained quercetin and luteolin together. However, 10 of the samples tested in this study (broccoli, green chili, bird chili, onion leaves, belimbi leaves, French bean, carrot, white radish, limau purut leaves, and dried asam gelugur) contained these two compounds together.

Total Flavonoid Content. The highest total flavonoids content was found in onion leaves, which contained 1497.5 mg/kg quercetin, 391.0 mg/kg luteolin, and 832.0 mg/kg kaempferol. Onion leaves, like onions, have the potency to become the major dietary source of flavonoids. Onion is one of the important sources of dietery flavonoids, and it contains a range of quercetin, isorhamnetin, and kaempferol conjugates (*18*, *19*). Semambu leaves (2041.0 mg/kg) showed the second highest total flavonoids content. Semambu leaves have medicinal and antiseptic properties (*20*). Bird chili (1663.0 mg/kg) showed the third highest content of flavonoid, followed by black tea (1491.0 mg/kg), papaya shoots (1264.0 mg/kg), and guava (1128.5 mg/kg).

Only trace quantities (less than 100 mg/kg) of total flavonoids could be detected in turmeric (92.5 mg/kg), green chili (83.5 mg/kg), soybean sprout (78.5 mg/kg), snake gourd (73.9 mg/kg), limau purut leaves (72.0 mg/kg), white radish (65.0 mg/kg), mint (48.5 mg/kg), selom (45.5 mg/kg), sengkuang (37.0 mg/kg), red spinach (29.5 mg/kg), and kailan (14.5 mg/kg) (Table 1).

Flavonoids in Black Tea. Black tea is an important dietary source of flavonoids. No apigenin or luteolin could be detected in black tea. Quercetin was in general the most important flavonoid found in tea (*21*). The black tea sample used in this study contained 303.0 mg/kg myricetin, 1070.0 mg/kg quercetin, and 118.0 mg/kg kaempferol. Fieschi et al. (*22*) determined the total flavonoid glycoside and aglycon contents of different types of black tea infusions using paper chromatography followed by spectrophotometric measurements. Total flavonoids content varied from 46 to 86 mg/L, and the content of flavonoid aglycons varied from 0.8 to 1.1 mg/L. According to Vinson et al. (*10*), flavonols found in tea are the most powerful natural antioxidants and it was 20 times more potent than the best vitamin ascorbic acid. Tea is considered one of the main dietary sources of flavonoids for adults in the UK but its limited use by young people is declining in favor of carbonated drinks and coffee, which are relatively low in flavonoids (*23*). Unfermented/green tea is especially rich in polyphenol, flavonols, and catechins, whereas fermented black tea contains lesser amounts. In black tea infusions, quer-

Table 1. Flavonoid Content in 62 Malaysian Edible Plants

	sample	scientific name	content, mg/kg of dry weight[a]					
			total flavonoid	myricetin	quercetin	luteolin	kaempferol	apigenin
1	broccoli	*Brassica oleracea*	197.0	62.5 ± 0.06ef	60.0 ± 0.10c	74.5 ± 0.05c	ND	ND
2	cauliflower	*Brassica oleracea*	219.0	ND	219.0 ± 0.03c	ND	ND	ND
3	cabbage	*Brassica oleracea*	147.5	147.5 ± 0.05ef	ND	ND	ND	ND
4	Chinese cabbage	*Brassica oleracea*	218.0	31.0 ± 0.10ef	ND	ND	ND	187.0 ± 0.05bc
5	kailan	*Brassica alboglabra*	14.5	ND	14.5 ± 0.03c	ND	ND	ND
6.	green chili	*Capsicum annum*	83.5	11.5 ± 0.02f	ND	33.0 ± 0.20c	39.0 ± 0.03e	ND
7	red chili	*Capsicum annum*	829.0	29.5 ± 0.04ef	799.5 ± 0.03ab	ND	ND	ND
8	bell pepper	*Capsicum annum*	892.0	171.5 ± 0.02ef	448.5 ± 0.05bc	ND	ND	272.0 ± 0.02b
9	bird chili	*Capsicum frutescens*	1663.0	236.0± 0.03def	392.0 ± 0.02bc	1035.0 ± 0.03a	ND	ND
10	Chinese chives	*Allium odorum*	160.0	ND	160.0± 0.03c	ND	ND	ND
11	onion leaves	*Allium fistulosum*	2720.5	ND	1497.5 ± 0.01a	391.0 ± 0.05b	832.0 ± 0.05a	ND
12	garlic	*Allium sativum*	957.0	693.0 ± 0.05ab	47.0 ± 0.01c	ND	ND	217.0 ± 0.02ab
13	belimbi fruit	*Averrhoa belimbi*	806.0	146.0 ± 0.02ef	ND	202.0 ± 0.05bc	ND	458.0 ± 0.04a
14	belimbi leaves	*Averrhoa belimbi*	532.0	27.0 ± 0.03ef	40.5 ± 0.05c	464.5 ± 0.05b	ND	ND
15	yam stalk	*Colocasia esculentum*	133.5	133.5 ± 0.05ef	ND	ND	ND	ND
16	tapioca shoots	*Manihot utilissima*	512.0	ND	512.0 ± 0.07bc	ND	ND	ND
17	sweet potato shoots	*Ipomoea batatas*	ND	ND	ND	ND	ND	ND
18	papaya shoots	*Carica papaya*	1264.0	ND	811.0 ± 0.06ab	ND	453.0 ± 0.07b	ND
19	cashew shoots	*Anacardium occidentale*	450.5	188.0 ± 0.01ef	262.5 ± 0.05c	ND	ND	ND
20	fern shoots	*Diplazium esculentum*	213.0	ND	213.0 ± 0.02c	ND	ND	ND
21	soybean sprout	*Glycine max*	78.5	ND	78.5 ± 0.05c	ND	ND	ND
22	mungbean sprout	*Phaseolus aureus*	268.0	60.0 ± 0.02ef	208.0 ± 0.05c	ND	ND	ND
23	lady's fingers	*Hibiscus esculentus*	260.0	54.5 ± 0.05ef	205.5 ± 0.05c	ND	ND	ND
24	winged bean	*Psophocarpus tetragonolobus*	ND	ND	ND	ND	ND	ND
25	French bean	*Phaseolus vulgaris*	172.5	47.0 ± 0.04ef	114.5 ± 0.05c	11.0 ± 0.07c	ND	ND
26	French peas	*Pisum sativum*	361.0	48.5 ± 0.01ef	136.5 ± 0.05c	ND	ND	176.0 ± 0.01bc
27	string bean	*Vigna sinensis*	ND	ND	ND	ND	ND	ND
28	petai	*Parkia speciosa*	ND	ND	ND	ND	ND	ND
29	peria	*Momordica charantia*	ND	ND	ND	ND	ND	ND
30	brinjal	*Solanum melongena*	219.5	39.5 ± 0.05ef	ND	ND	80.0± 0.05cde	ND
31	angular loofah	*Luffa acutangula*	675.5	433.5 ± 0.04cd	242.0 ± 0.03c	ND	ND	ND
32	snake gourd	*Trichosanthes anguina*	73.9	31.5 ± 0.05ef	ND	ND	ND	42.4 ± 0.01c
33	pumpkin	*Cucurbita maxima*	371.0	ND	ND	ND	371.0± 0.03bc	ND
34	sengkuang	*Pachyrrhizus erosus*	37.0	ND	ND	ND	37.0 ± 0.01e	ND
35	guava	*Psidium guajava*	1128.5	549.5 ± 0.05bc	ND	ND	ND	579.0 ± 0.02a
36	carrot	*Daucus carota*	232.5	ND	55.0 ± 0.05c	37.5 ± 0.05c	140.0 ± 0.06cde	ND
37	white radish	*Raphanus sativus*	65.0	ND	17.5 ± 0.05c	9.0 ± 0.07c	38.5 ± 0.05e	ND
38	red spinach	*Amaranthus gangeticus*	29.5	ND	29.5 ± 0.05c	ND	ND	ND
39	bayam duri	*Amaranthus spinosus*	ND	ND	ND	ND	ND	ND
40	Kangkung	*Ipomoea aquatica*	205.0	ND	205.0 ± 0.06 c	ND	ND	ND
41	wolfberry leaves	*Lycium chinense*	678.5	ND	131.5 ± 0.05c	ND	ND	547.0 ± 0.07a
42	drumstick leaves	*Moringa oleifera*	232.5	ND	232.5 ± 0.02c	ND	ND	ND
43	local celery	*Apium graveolens*	419.0	ND	ND	80.5 ± 0.05c	ND	338.5 ± 0.04a
44	limau purut leaves	*Citrus hystrix*	72.0	ND	41.5 ± 0.05c	30.5 ± 0.05c	ND	ND
45	daun turi	*Sesbania grandifolia*	306.0	27.0 ± 0.01ef	18.5 ± 0.05c	ND	21.0 ± 0.03bcde	39.5 ± 0.04c
46	betel leaves	*Piper betel*	ND	ND	ND	ND	ND	ND
47	pandan leaves	*Pandanus odorus*	123.5	ND	123.5 ± 0.02c	ND	ND	ND
48	lemon grass	*Cymbopogon citratus*	178.0	ND	ND	ND	178.0 ± 0.07cde	ND
49	semambu leaves	*Calamus scipronum*	2041.0	853.0 ± 0.06a	1188.0 ± 0.05a	ND	ND	ND
50	kesom leaves	*Polygonum minus*	308.5	126.5 ± 0.02ef	182.0 ± 0.07c	ND	ND	ND
51	maman	*Gynandropsis gynandra*	357.5	129.0 ± 0.09ef	228.5 ± 0.03c	ND	ND	ND
52	Kadok	*Piper sarmentosum*	120.5	55.5 ± 0.07ef	30.5 ± 0.06c	ND	ND	34.5 ± 0.05c
53	cekur manis	*Sauropus androgynus*	785.0	ND	461.5 ± 0.05bc	ND	323.5 ± 0.01bcd	ND
54	selom	*Oenanthe javanica*	45.5	ND	45.5 ± 0.02c	ND	ND	ND
55	pegaga	*Hydrocotyle asiatica*	444.0	ND	423.5 ± 0.07bc	ND	20.5 ± 0.05e	ND
56	bunga kantan	*Phaeomeria speciosa*	307.0	ND	21.0 ± 0.07c	ND	286.0 ± 0.05b	ND
57	plaintain flower	*Musa sapientum*	ND	ND	ND	ND	ND	ND
58	asam gelugor	*Garcinia atroviridus*	292.5	77.0 ± 0.07ef	108.0 ± 0.07c	107.5 ± 0.05c	ND	ND
59	turmeric	*Curcuma longa*	92.5	ND	92.5 ± 0.03c	ND	ND	ND
60	mint	*Mentha arvensis*	48.5	ND	48.5 ± 0.08c	ND	ND	ND
61	oyster mushroom	*Pleurotus sajor-caju*	ND	ND	ND	ND	ND	ND
62	black tea	*Camellia chinensis*	1491	303.0 ± 0.02de	1070.0 ± 0.09a	ND	118.0 ± 0.02ed	ND

[a] Each value is the mean (mg/kg of dry weight) of two replications ± standard deviation; ND = not detectable. Means in each column with similar letters are not significantly different (α = 0.05).

cetin (10−25 mg/L), kaempferol (7−17 mg/L), and myricetin (2−5 mg/L) were detected. Because flavonol glycosides are not affected by polyphenoloxidase as with catechins, their content in black tea is at nearly the same level as in the green leaves. Flavonol glycosides are one of the most important groups of polyphenols in tea. They are of interest because of their physiological activity, in particular the so-called vitamin P effect (regulation of capillary permeability) and the hypertensive effect (*24*).

Flavonoids in *Brassica* spp. Among the five types of *Brassica* spp. used in this study, none of the samples contained kaempferol. The major flavonoids in *Brassica* spp. are myricetin and quercetin. Three types of flavonoids were found in broccoli (62.5 mg/kg myricetin, 60.0 mg/kg quercetin, and 74.5 mg/kg luteolin), and two were found in Chinese cabbage (31 mg/kg myricetin and 187.0 mg/kg apigenin). In general, the values found in this study are somewhat higher than values reported earlier by Hertog et al (*17*). In their study, none of the

Table 2. Comparison of Flavonoid Levels in Edible Plants Found in the Present Study and Levels Reported in Previous Studies

sample	compound	present study (mg/kg)	previous study (mg/kg)	reference
1. broccoli	myricetin	62.5	NA[a]	NA
	quercetin	60.0	30.0	*17*
			6.0	*30*
			0.092	*47*
	luteolin	74.5	NA	NA
	kaempferol	ND[b]	72.0	*17*
			30.0	*30*
2. cauliflower	quercetin	219.0	< 1.0	*17*
			30.0	*30*
	kaempferol	ND	< 2.0	*17*
			270.0	*30*
3. bell pepper	myricetin	171.5	<1.0	*17*
	quercetin	448.5	NA	NA
	luteolin	ND	13−31	*17*
	apigenin	272.0	NA	NA
4. french bean	myricetin	47.0	NA	NA
	quercetin	114.5	32−45	*17*
	luteolin	11.0	NA	NA
	kaempferol	ND	<2−14	*17*
5. carrot	myricetin	ND	<1.0	*17*
	quercetin	55.0	<1.0	
	luteolin	37.5	<1.4	
	kaempferol	140.0	<1.0	
6. Chinese cabbage	myricetin	31.0	NA	NA
	quercetin	ND	3.0	*30*
	kaempferol	ND	11.0	
	apigenin	187.0	NA	NA
7. black tea	myricetin	303.0	200−500	*21*
	quercetin	1070.0	1000−2500	
	kaempferol	118.0	700−1700	
8. garlic	myricetin	693.0	NA	NA
	quercetin	47.0	0.08	*47*
	apigenin	217.0	NA	NA
9. soybean sprout	quercetin	78.5	0.042	*47*

[a] NA = no data available. [b] ND = non-detectable.

flavonoids investigated could be found in the Brassicas tested except broccoli (30.0 mg/kg quercetin and 72.0 mg/kg kaempferol), kale (110.0 mg/kg quercetin and 211.0 mg/kg kaempferol), and turnip tops (7.3 mg/kg quercetin and 48.0 mg/kg kaempferol). Nielson et al. (*25*) found kaempferol and quercetin glycosides present in cabbage leaves. Mono-, di- and triglycosides of kaempferol, quercetin, and isorhamnetin also have been identified from broccoli and other *Brassica* spp.

Flavonoid in Capsicums. The major flavonoids in capsicums are myricetin and quercetin. Quercetin was not detected in green chili. Bird chili contained the highest level of luteolin (1035.0 mg/kg) among all the samples tested. Therefore, consumption of bird chili may reduce risk of tumorigenesis because luteolin was shown to be a potent inhibitor to enzyme lipoxygenase and prostaglandin synthetase (*12*). Contents of flavonoids and other phenolics, including capsaicinoid, in bird chili vary with fruit maturation (*26*). Bell pepper contained 171.5 mg/kg myricetin, 448.5 mg/kg quercetin, and 272.0 mg/kg apigenin. Lee et al. (*27*) found that after acid hydrolysis, quercetin and luteolin were the major flavonoids in bell pepper. No luteolin was detected in the bell pepper used in this study.

Capsicums are generally spices of commercial value as they are used in the manufacture of sauces, curry powders, and pickles. They contain capsaicin, a phenolic compound closely related to vanillin, which gives the pungency to the capsicums and shows a significant antioxidative effect (*28*). Sukrasno and Yeoman (*26*) found that flavonoids were present as both flavones and flavonone glycoside conjugates in *C. frutescens*.

Bell peppers are a good source of vitamins A and C, which are important dietary antioxidants. The major pepper flavonoids were quercetin and luteolin, which were present in conjugate forms. Lee et al. (*27*) found that total flavonoids varied from non detectable to 800 mg/kg after hydrolysis. All yellow pepper fruit contained high levels of flavonoids. Quercetin was 2−12 times higher than luteolin in the 12 cultivars of the peppers they studied, and luteolin had the highest antioxidant activity,followed by capsaicin and quercetin on an equivalent basis.

Flavonoids in Allium Vegetables. Allium vegetables (onion leaves, Chinese chives leaves, and garlic) contained quite high levels of flavonoids. The total flavonoids in onion leaves is the highest among all the samples tested. Garlic contained 639.0 mg/kg myricetin, 47.0 mg/kg quercetin, and 217.0 mg/kg apigenin. Cao et al. (*29*) found that garlic had the highest antioxidant activity against peroxyl radical among the samples they tested. Only 160.0 mg/kg of quercetin could be detected in Chinese chives leaves. *Allium* spp. are reported to contain high levels of quercetin and its derivatives (*16*, *18*, *30*) such as isorhamnetin, which is one of the most biologically active and common dietary flavonols (*31*). Dietary intake of the flavonoids quercetin and its glycosides ranges between 23 and 500 mg per day (*32*, *33*).

Leighton et al. (*18*) found that flavonols levels in the edible portion of *Allium* vegetables (leeks, shallots, green onions, garlic, and onions) range from less than 0.03 to 1 g/kg of vegetables. White onions contained no detectable flavonols but 20 cultivars of yellow and red onions contained between 60 mg/kg and more than 1000 mg/kg. Flavonols identified in onions were 3 quercetin diglucosides, quercetin 4′-glucoside, quercetin aglycone, and in some cases, isorhamnetin monoglucosides or kaempferol monoglucosides.

Flavonoids in Some Locally Consumed Plants. Some of the locally consumed plants such as semambu leaves, papaya shoot, cekur manis, tapioca shoot, belimbi leaves, cashew shoot, pegaga, maman, kesom leaves, bunga kantan, and daun turi are found to be rich in flavonoid content.

Piper betel (Piperaceae) leaves are chewed alone or with other plant materials including the areca nut, *Areca catechu L.* (*34*). Seven phenols were identified in *P. betel* flowers. Safrole was the major phenol, followed by hydroxychavicol, eugenol, methyl eugenol, isoeugenol, flavone, and quercetin (*35*).

Flavonoids such as isorhamnetin, hyperoside, and persicarin were isolated from *Oenanthe javanica* (*36*).

The fruits and leaves of box thorn or Wolfberry leaves (*Lycium chinense*, family Solanaceae) have been used as foods, tea, and medicine in the orient. Box thorn leaves are known to be capable of reducing the risk of certain diseases such as arteriosclerosis, essential arterial hypertension, diabetes, and nightblindness (*37*). Box thorn leaves reportedly contain the anti-aging ascorbic acid and tocopherols (*38*). Mizobuchi et al. (*39*) reported that box thorn leaves contained rutin (1.1−2.7% dry weight basis), a preventive phytochemical for hypertension and stroke.

Rhizomes of *Curcuma spp.*, such as *C. longa* are used in traditional medicine in China, Japan, and southeastern Asia. The rhizomes of *C. longa* Salisb are also used as a yellow coloring additive for food because it contains curcuminoids (*40*).

Sudheesh et al. (*41*) found that flavonoid extracted from the fruits of *Solanum melongena* orally administered at a dose of 1 mg/100 g body weight/day showed hypolidemic action in normal and cholesterol-fed rats. This provides information on the potential beneficial action of flavonoid from brinjal in normal as well as cholesterol-fed animals.

Flavonols in the Plants Tested. Yoshida et al. (*9*) suggest that quercetin is a potent anticancer agent in man. Myricetin, with its three adjacent hydroxyl groups was one of the most active antioxidants (*12*). Myricetin is not only a good antioxidant, but also been shown to be a potent anticarcinogen and antimutagen (*42*). Quercetin is also a strong antioxidant that can contribute to the prevention of atherosclerosis (*11*). Quercetin is a suppressing chemopreventive and chemotherapeutic agent that can relieve local pain caused by inflammation, headache, oral surgery, and stomach ulcer (*1*). Recently, quercetin has been shown to reduce the carcinogenic activity of several cooked food mutagens, enhance the antiproliferative activity of anticancer agents, and inhibit the growth of transformed tumorigenic cells (*18*). Currently, kaempferol is in interest because of its antioxidant (*10, 12*), antitumor, antiinflammatory, and antiulcer activity (*43*), and its inhibitory activity of HIV protease (*44*). The flavones had the poorest antioxidant activity because of lack of *o*-dihydroxy groups. Kaempferol and its derivative have been identified in various vegetables, fruits, and beverages such as French beans (*45*), onions (*31*), teas (*21*), and honey (*46*).

In general, flavonoid levels reported in this study were higher than values reported earlier by Herrmann (*30*), Hertog et al. (*16, 21*), and Mizuno et al. (*47*) (Table 2). The procedural differences of the studies, as well as the characteristics of the varieties examined, may explain this difference. The thin-layer chromatographic method with spectrophotometric measurement applied by Herrmann (*30*) may lack precision and accuracy. In this study only the edible plant parts were analyzed, whereas Herrmann (*30*) generally analyzed the whole plant. Discrepancies may also be due to cultivars or varietal differences. Crozier et al. (*23*) found that there was variation in the levels of quercetin in cherry tomatoes purchased at different times.The concentrations of flavones and flavonols, like those of all secondary plant metabolites, vary within certain limits and are dependent on a number of factors: for example, growing condition, degree of ripeness, size of the fruit, and variety.

Cao et al. (*48*) reported that consumption of controlled diets high in fruits and vegetables increased significantly the antioxidant capacity of plasma, and the increase could not be explained by the increase in the plasma α-tocopherol or carotenoid concentration. On a milligram-per-day basis, the intake of the antioxidant flavonoids still exceeds that of the antioxidant β-carotene and vitamin E. Thus, flavonoids represent an important source of antioxidant activity in the human diet (*33*). Supplementation of these natural antioxidants through a balanced diet could be much more effective and economical than supplementation of an individual antioxidant, such as ascorbic acid or α-tocopherol, in protecting the body against various oxidative stresses.

Polyphenols are effective hydrogen donors, particularly flavonols such as quercetin (*49*). Studies on the natural antioxidants flavonoids and phenolics compounds in temperate edible plants are quite established (*50*). These foods include tea, alliums, tomatoes, lettuce, and celery (*14, 23*); apples, 28 vegetables, 9 fruits, citrus fruit juices such as fresh orange, grapefruit, and lemon juices (*21*); beer, coffee, chocolate milk, white wine, tea infusion, and red wine (*51, 52*); apple juice, tomato juice, grape juice, orange juice, grapefruit juice and lemon juice, cauliflower, radish, pea, broccoli, Chinese cabbage, and carrot (*30*); sixteen leafy vegetables and fruits such as *Colocasia*, cabbage, and *Hibiscus sabdariffa* (*53*); lettuce, kale, chive, garlic chive, leek, horseradish, red radish, and red cabbage tissues (*54*); soybean sprouts, Japanese radish, grapefruit, and burdock root (*47*); citrus fruits (*30, 55*); juices of orange, apple, pineapple, peach, apricot, pear, and grape (*56*).

Hermann (*30*) and Balestieri et al. (*55*) reported that citrus fruits contain almost exclusively flavanones. Quercetin was also found in some of the citrus fruit juices such as fresh orange, grapefruit, and lemon juices (*21*). Flavanones, flavones, and flavonols are the flavonoids present in citrus. However, flavones and flavonols were in low concentration in citrus tissues in relationship to flavanones. These types of compounds have been shown to be powerful antioxidants and free radical scavengers. (*57*).

Effect of Drying Temperature on Flavonoid Content. Phenolic compounds are usually susceptible to different factors (eg., acidic solution and high temperature) during the extraction process. Drying at temperatures below 50 °C yields the highest amount of total phenolics (*58*). Drying at room temperature may enhance the enzymatic degradation and thus lower the amount of phenolics in the samples. Increasing the temperature above 60 °C lowered the phenolic amount considerably. At high temperatures, certain phenolics may decompose/combine with the other plant components. Cooking lowered the quercetin content of both tomatoes and onions, with greater reduction being detected following microwaving and boiling than after frying (*23*). This could be due to flavonoid breakdown during cooking and/or conjugated quercetin being extracted from the tomato and onion tissues by hot water more effectively than with hot oil used in the study. Price et al. (*59*) found that there are only little gross changes in either the overall level or the composition of quercetin glucosides during normal commercial storage. Boiling and frying do not result in gross changes in glucosides composition, although an overall loss of up to 25% is found for both processes, in the former by leaching into the cooking water and in the latter by thermal degradation into products.

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Received for review July 18, 2000. Revised manuscript received November 15, 2000. Accepted November 15, 2000.

JF000892M